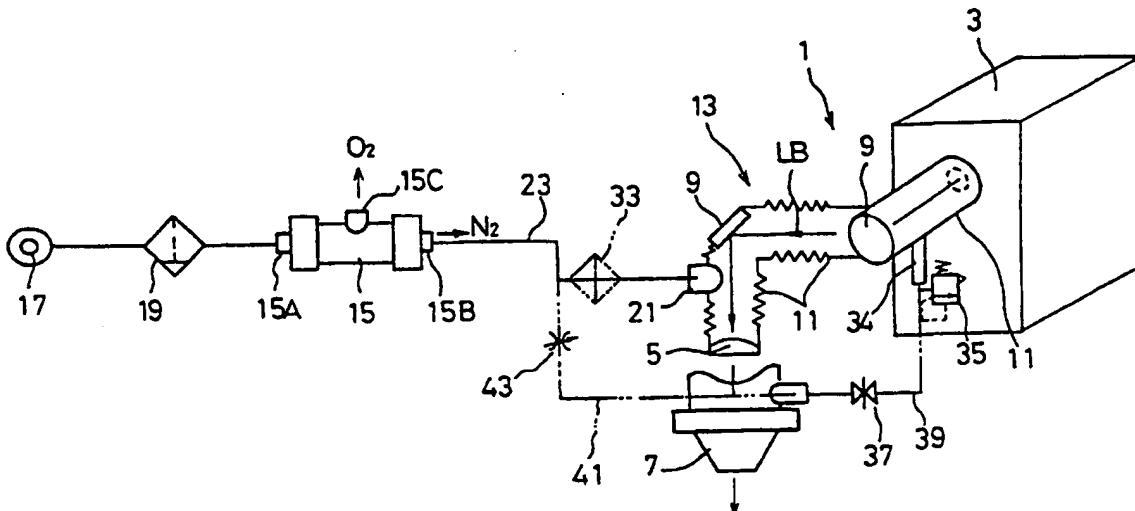


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(54) Title: METHOD AND APPARATUS FOR SUPPLYING GASEOUS NITROGEN TO A LASER BEAM MACHINE



(57) Abstract

Oxygen and nitrogen contained in air is separated by an air separator (15). The separated nitrogen gas is supplied to the optical path cover (11) of the laser beam machine as a protective gas for bend mirrors (9). Further, the separated nitrogen gas or oxygen gas can be selectively supplied to the laser beam head (7) as an assist gas. Further, the purity of the separated nitrogen gas can be kept within a predetermined range (94 to 99.5 %) on the basis of a difference in pressure between a first conduit (47) for supplying nitrogen gas and a second conduit (49) for supplying oxygen gas. Further, it is preferable to provide a filter (19) for removing dust from air supplied to the air separator and a second filter (33) for removing oil mist from the separated nitrogen supplied to the optical path cover (11).

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## DESCRIPTION

## METHOD AND APPARATUS FOR SUPPLYING GASEOUS NITROGEN TO A LASER BEAM MACHINE.

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## Technical Field

The present invention relates to a method and apparatus for supplying nitrogen gas to an optical path system of and a laser head provided both for a laser beam machine, and a laser beam machine provided with the same apparatus. Here, nitrogen gas is supplied to an optical path system to protect bend mirrors arranged in the optical path system, and further to a laser beam head as an assist gas.

## Background Art

As is well known, a laser beam machine is provided with a laser beam oscillator and a laser beam head. Further, a plurality of bend mirrors are arranged between the laser beam oscillator and the laser beam head, to guide the laser beam generated by the laser beam oscillator to the laser beam head.

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Here, the laser beam path from the laser beam oscillator to the laser beam head is referred to as an optical path system, which is usually partitioned from outside air by use of a pipe member for safety and for dust prevention.

Further, in the laser beam machine of movable laser beam head type, since the optical path length from the laser beam oscillator to the laser beam head changes, both are connected by use of a bellows or a telescopic tube, etc.

In addition, in order to prevent outside air from entering the optical path system, dry air cleaned by an air drying unit is usually supplied into the optical path system to protect various optical elements such as bend 5 mirrors, lenses, etc.

In the above-mentioned conventional construction of the laser beam machine, since the dry and clean air is supplied into the optical path system for prevention of 10 outside air from entering the optical path system, dust is extremely little as compared with outside air. However, there exists a problem in that the optical elements deteriorate by oxygen or a very small amount of moisture contained in the dry and clean air, when the laser beam 15 machine has been used for many hours.

In addition, an assist gas such as air, oxygen, nitrogen, argon, etc. is usually used in the laser beam machining, which is appropriately selected according to the 20 sort of plate materials, laser beam machining conditions, etc.

However, air, oxygen and nitrogen are used generally as the assist gas, because argon is costly (except the case 25 where the material to be processed is titanium).

In the case where air is used as the assist gas, a compressed air can be obtained easily by use of a compressor. In the case of oxygen or nitrogen, however, an 30 oxygen bomb or a nitrogen bomb must be prepared, so that the assist gas is not economical.

To overcome these problem, Japanese Published Unexamined (Kokai) Patent No. 5-84590 (referred to as a 35 prior art, hereinafter) discloses such a construction that oxygen and nitrogen in air are separated from each other by an air separator so that the separated oxygen and nitrogen

can be used as the assist gas. In this method, since oxygen and nitrogen in air can be used after separation without using any gas bombs, the assist gas can be obtained at a relatively low cost.

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In the above-mentioned method, however, since the pressure of the assist gas supplied to the laser beam head must be adjusted according to the laser beam machining conditions, there exists another problem in that the purity 10 of oxygen or nitrogen separated by the air separator varies whenever the assist gas pressure is adjusted, with the result that a harmful influence is produced upon the laser beam processing.

15 Disclosure of Invention

With these problems in mind, therefore, it is the object of the present invention to provide a method and apparatus for protecting the optical path system more reliably from deterioration (due to oxidization, moisture, 20 etc.), instead of dry and clean air.

Further, the other object of the present invention is to effectively use the separated nitrogen (to be introduced into the optical path system as a protective gas) as an 25 assist gas simultaneously.

Further, the other object of the present invention is to supply the separated nitrogen gas as the assist gas within a constant purity range (94 to 99.5%) whenever the 30 assist gas pressure is adjusted according to the laser beam processing conditions.

To achieve the above-mentioned object, the present invention provides a method of supplying nitrogen gas into 35 an optical path system of a laser beam machine, which comprises the following steps of: supplying compressed air into an air separator (15) for separating oxygen and

nitrogen from the supplied compressed air; and introducing nitrogen-rich gas separated by the air separator into an optical path cover (11) of the optical path system (13) of the laser beam machine, to maintain an inner pressure of 5 the optical path cover at a pressure higher than outside air pressure.

Further, it is preferable that the method further comprises the step of passing the nitrogen-rich gas 10 separated by the air separator through a filter (33) for removing oil mist, before the nitrogen-rich gas is introduced into the optical path cover (11) of the optical path system (13) of the laser beam machine.

15 Further, the present invention provides an apparatus for supplying nitrogen gas into an optical path system of a laser beam machine, which comprises: an air separator (15) for separating oxygen and nitrogen from compressed air; and conduit means (23) for introducing nitrogen-rich gas 20 separated by said air separator into an optical path cover (11) of the optical path system (13) of the laser beam machine.

Further, it is preferable that the apparatus further 25 comprises: a first filter (19) for removing dust from the compressed air, before the compressed air is supplied to said air separator; and a second filter (33) for removing oil mist contained in the nitrogen-rich gas, before the nitrogen-rich gas is introduced into the optical path cover 30 of the optical path system of the laser beam machine.

Further, the present invention provides a laser beam machine, comprising: an air separator (15) for separating oxygen and nitrogen from compressed air; first conduit 35 means (23) for introducing nitrogen-rich gas separated by said air separator into an optical path cover (11) of the laser beam machine as a protective gas; and second conduit

means (39, 41, 47) for introducing the nitrogen-rich gas separated by said air separator into a laser beam head (7) of the laser beam machine as an assist gas.

5       Further, it is preferable that the laser beam machine further comprises: a first filter (19) for removing dust from the compressed air, before the compressed air is supplied to said air separator; and a second filter (33) disposed in said first conduit means (23), for removing oil mist contained in the nitrogen-rich gas, before the nitrogen-rich gas is introduced into the optical path cover of the laser beam machine.

15      Further, said second conduit means is a conduit (39) connected between the optical path cover (11) and the laser beam head (7), for supplying the nitrogen-rich gas into the laser beam head as the assist gas.

20      Further, said second conduit means is a branch conduit (41) connected between said air separator and the laser beam head (7), for supplying the nitrogen-rich gas into the laser beam head as the assist gas.

25      Further, said second conduit means comprises: a first conduit (47) connected between a first outlet port (15B) of said air separator (15), for discharging the nitrogen-rich gas; and a second conduit (49) connected between a second outlet port (15C) of said air separator (15), for discharging the oxygen-rich gas.

30      Further, it is preferable that the laser beam machine further comprises: a first change-over valve (55A) disposed midway of said first conduit (47), for supplying the nitrogen-rich gas into the laser beam head when opened; and a second change-over valve (55B) disposed midway of said second conduit (49), for supplying the oxygen-rich gas into the laser beam head when opened.

Further, it is preferable that the laser beam machine further comprises: a first pressure control valve (51A) disposed midway of said first conduit (47), for controlling pressure in said first conduit; and a second pressure control valve (51B) disposed midway of said second conduit (49), for controlling pressure in said second conduit.

Further, purity of the nitrogen-rich gas increases when the pressure in said first conduit is increased by said first pressure control valve (51A), but decreases when the pressure therein is decreased thereby.

Or else, purity of the nitrogen-rich gas increases when the pressure in said first conduit is kept constant by said first pressure control valve (51A) and when the pressure in said second conduit is decreased by said second pressure control valve (51B), but decreases when the pressure in said first conduit is kept constant by said first pressure control valve (51A) and when the pressure in said second conduit is increased by said second pressure control valve (51B).

Further, purity of the nitrogen-rich gas can be kept roughly constant when a difference in pressure between said first and second conduits (47, 49) is kept roughly constant.

Further, it is preferable that the laser beam machine further comprises: a first control valve (65A) for remote-controlling said first pressure control valve (51A); and a second control valve (65B) for remote-controlling said second pressure control valve (51B).

Further, it is preferable that the laser beam machine further comprises an link mechanism (69) for controlling said first and second pressure control valves (51A, 51B)

simultaneously in linkage so that a difference in pressure between said first and second conduits (47, 49) can be kept roughly constant.

5        In the laser beam machine according to the present invention, since the nitrogen-rich gas containing an extremely small amount of oxygen and moisture is supplied into the optical path system at pressure higher than the atmospheric pressure, it is possible to effectively prevent 10 fire accident of the optical path system and to protect the optical parts from deterioration due to oxidization and moisture, as compared with the conventional dry air.

15        Further, in the laser beam machine according to the present invention, since the nitrogen-rich gas can be also supplied to the laser beam head as an assist gas, it is possible to effectively use the nitrogen-rich gas separated by the air separator. Further, oxygen gas separated by the air separator can be also used as an assist gas.

20        Further, in the laser beam machine according to the present invention, since the nitrogen-rich gas can be supplied to the laser beam head as an assist gas by keeping the purity of the nitrogen-rich gas or the oxygen-rich gas 25 at a desired constant level or in a predetermined range (e.g., 94 to 99.5%) at all times, it is possible to prevent the occurrence of dross during the laser beam processing.

30        Further, in the laser beam machine according to the present invention, since the first filter for removing dust from air supplied to the air separator and the second filter for removing oil mist from the separated nitrogen supplied to the optical path cover, it is possible to 35 improve the lifetime of the optical parts of the optical path system.

Brief Description of Drawings

Fig. 1 is a diagrammatical illustration showing a first embodiment of the laser beam machine according to the present invention;

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Figs. 2A and 2B are illustrations for assistance in explaining the oil mist adhesion test method and the test results, respectively;

10 Fig. 3 is a diagrammatical illustration showing a second embodiment of the laser beam machine according to the present invention; and

15 Fig. 4 is a diagrammatical illustration showing a third embodiment of the laser beam machine according to the present invention.

Best Mode for Carrying Out the Invention

20 Embodiments of the laser beam machine according to the present invention will be described hereinbelow with reference to the attached drawings.

25 In Fig. 1, the laser beam machine 1 is provided with a laser beam oscillator 3 and a laser beam head 7 having a condenser lens 5. The laser beam oscillator 3 is connected to the laser beam head 7 via an optical path system 13 composed of a plurality of bend mirrors 9 and an optical cover 11. The bend mirrors 9 guide a laser beam LB generated by the laser beam oscillator 3 to the laser beam head 7. The optical cover 11 is an appropriate pipe member, bellows, telescopic tube, etc. Further, the optical path system 13 is the same as with the case of the prior art one, so that any detailed description thereof is 30 omitted herein.

35

In addition, an air separator 15 is provided to

separate oxygen and nitrogen from compressed air. The separated nitrogen-rich gas is supplied into the optical path cover 11 to protect the optical path system 13. The air separator 15 is a module in which a great number of 5 hollow threads (formed of polyimide) are arranged in a lump within a vessel. The hollow polyimide thread membrane is provided with such a function as to permeate oxygen more easily than nitrogen.

10 Therefore, when compressed air is supplied into the air separator 15 through an inlet port 15A and therefore flows through the hollow threads, since oxygen, moisture and oil mist of the compressed air are selectively passed through the membranes of the polyimide hollow threads, it 15 is possible to obtain a nitrogen-rich gas (purity: 94 to 99.5%) from a first outlet port 15B. On the other hand, the permeated oxygen, moisture and oil mist are discharged through a second outlet port 15C as oxygen-rich gas. The above-mentioned nitrogen-rich gas (obtained by removing 20 oxygen, moisture and oil mist from air) is dry air (nitrogen) having a dew point of about -50 degrees under atmospheric pressure. In comparison with the ordinary refrigerator drier having a dew point of about - 10 degrees under atmospheric pressure, it can be understood that the 25 nitrogen-rich gas is extremely advantageous when used to protect the optical path system 13.

To supply compressed air into the air separator 15, a pressure source 17 such as a compressor is provided. 30 Further, a filter 19 is connected between the pressure source 17 and the inlet port 15A of the air separator 15, to remove dust and oil mist contained in the high pressurized air obtained by the pressure source 17.

35 Further, to supply the nitrogen-rich gas separated from the compressed air by the air separator 15 into the optical path cover 11 of the optical path system 13, a

conduit (pipe) 23 is connected between the first outlet port 15B of the air separator 15 and a junction port 21 of the optical path cover 11. Further, the second outlet port 15C of the air separator 15 is opened to the atmospheric pressure.

In the above-mentioned construction, after having been passed through the filter 19 for removal of dust and oil mist, the compressed air of the pressure source 17 is supplied to the air separator 15 through the inlet port 15A. The compressed air supplied into the air separator 15 through the inlet port 15A is separated into oxygen (containing moisture, residual oil mist (passed through the filter 19)) and nitrogen when being passed through the hollow thread membranes. As a result, it is possible to obtain nitrogen-rich gas (purity: 94 to 99.5%) through the first outlet port 15B and the oxygen-rich gas passed through the second outlet port 15C of the air separator 15, respectively.

20

In this case, since the nitrogen-rich gas is dry air having a dew point of about -50 degrees under atmospheric pressure, when supplied into the optical path cover 11 of the optical path system 13 through the conduit 23, it is possible to maintain the pressure within the optical path cover 11 higher than the atmospheric pressure.

In other words, since the optical cover 11 is kept at a pressure higher than the atmospheric pressure and further filled with nitrogen-rich dry air containing extremely small oxygen (nitrogen purity: 94 to 99.5%), it is possible to protect the optical cover 11 from fire accident or the optical parts (e.g., the bend mirrors 9) from deterioration (e.g., due to oxidization or moisture) more effectively, as compared with the conventional case in which the dry air is supplied into the optical path system.

In the above description, the nitrogen-rich gas is simply introduced into the optical path cover 11 for protection of the optical path system 13. Here, however, it is possible to consider that the dry air can be directly jetted against the bend mirrors 9 to clean the surfaces of the bend mirrors 9. To check the possibility of the direct jetting of the dry air against the bend mirrors 9 for surface cleaning, the following tests were made:

As shown in Fig. 2(A), a test conduit 27 is connected to the first outlet port 15B of the air separator 15, instead of the conduit 23. A test mirror 25 is held in air about 50 mm distance away from an end 27E of the test conduit 27. Further, a conical cover 29 is attached near the end of the test conduit 27 for prevention of external air from being introduced.

In the above-mentioned construction, nitrogen-rich gas was directly jetted against the test mirror 25. In this test, however, it was confirmed some oil mist 31 adhering onto the surface of the test mirror 25 after about six hours.

The above-mentioned test indicates that the nitrogen-rich gas still contains a small amount of oil mist. Therefore, when the nitrogen-rich gas is directly jetted against the bend mirrors 9 to clean the surfaces thereof, although the bend mirrors 9 are not degraded in a short time, there exists a possibility that the bend mirrors 9 deteriorate after the use of a longer time (e.g., several hours or more).

To overcome the above-mentioned problem, as shown in Fig. 2(B), a filter 33 having active carbon (charcoal) was connected midway to the test conduit 27, and the similar test was made. In this case, it was confirmed that no oil mist was confirmed on the surface of the test mirror 25

even after 400 hours. The above-mentioned test indicates that it is extremely effective to remove oil mist by use of the filter 33 having active carbon.

5        Accordingly, in the laser beam machine as shown in Fig. 1, it is desirable to connect the filter 33 having active carbon to the conduit 23, in order to firmly remove a small amount of oil mist still remaining in the nitrogen-rich gas.

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Here, it is also possible to interpose the filter 33 having active carbon between the filter 19 and the inlet port 15A of the air separator 15. In this case, however, since all amount of compressed air supplied to the air 15 separator 15 must be filtered, it is preferable to interpose the filter 33 on the side of the conduit 23 from the standpoint of the lifetime of the filter 33.

20        On the other hand, the pressure within the optical path cover 11 of the optical system 13 is kept higher than the atmospheric (outside air) pressure. In this case, it is possible to construct the optical path cover 11 in such a way that part of the supplied nitrogen-rich gas can be discharged to the outside through an appropriate gap formed 25 between the connection portions of some elements of the optical path cover 11. In this embodiment, however, in order to maintain the pressure within the optical path cover 11 under a stable constant value, an discharge port 34 is formed at a position of the optical path cover 11 and 30 further a relief valve 35 is connected to this discharge port 34.

As a result, since the inner pressure within the optical path cover 11 can be adjusted at a constant level 35 through the relief valve 35, even if the volume of the optical path cover 11 is decreased or increased and thereby the inner pressure thereof increased or decreased as when

the laser beam head 7 is moved, it is possible to always maintain the inner pressure within the optical path cover 11 at a constant pressure level. Therefore, it is possible to prevent the bend mirrors 9 from being distorted due to 5 fluctuations of inner pressure.

Further, in the present invention, since the nitrogen-rich gas is effectively used as a protective gas for the optical path system 13, the discharge port 34 of the 10 optical path cover 11 can be connected to the laser beam head 7 through a conduit 39 having a shut-off valve 37 connected midway thereof. In other words, it is possible to use the nitrogen-rich gas in the optical path cover 11 as an assist gas at need. In this case, the nitrogen-rich 15 gas can be used more effectively.

Further, it is also possible to connect a branch pipe 41 having a throttle valve 43 between the conduit 23 and the laser beam head 7, so that the nitrogen-rich gas can be 20 directly supplied into the laser beam head 7 as an assist gas. In this case, as far as the amount of the nitrogen-rich gas within the conduit 23 is sufficient, it is possible to use the nitrogen-rich gas as the assist gas, without exerting a harmful influence upon the pressure 25 within the optical path cover 11.

A second embodiment of the laser beam machine will be described hereinbelow with reference to Fig. 3. In this second embodiment, the nitrogen-rich gas can be supplied to 30 the laser beam head as the assist gas under a stably pressure condition.

In Fig. 3, an air separator 15 is provided to separate oxygen and nitrogen from compressed air. The structure of 35 the air separator 15 is quite the same in structure as with the case of the first embodiment. That is, the air separator 15 is a module in which a great number of hollow

threads (formed of polyimide) are arranged in a lump in a vessel. The hollow polyimide thread membranes are provided with such a function as to permeate oxygen more easily than nitrogen both contained in air.

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Therefore, when compressed air is supplied into the air separator 15 through an inlet port 15A and therefore flows through the hollow threads, since oxygen, moisture and oil mist of the compressed air are selectively passed through the membranes of the polyimide hollow threads, it is possible to obtain a nitrogen-rich gas (purity: 94 to 99.5%) from a first outlet port 15B. On the other hand, the permeated oxygen, moisture and oil mist are discharged through a second outlet port 15C as oxygen-rich gas. The above-mentioned nitrogen-rich gas (obtained by removing oxygen, moisture and oil mist from air) is dry air (nitrogen) having a dew point of about -50 degrees under atmospheric pressure. In comparison with the ordinary refrigerator drier having a dew point of about - 10 degrees under atmospheric pressure, it can be understood that the nitrogen-rich gas is extremely advantageous when used to protect the optical path system 13.

To supply compressed air into the air separator 15, a pressure source 17 such as a compressor is provided. Further, a filter 19 is connected between the pressure source 17 and the inlet port 15A of the air separator 15 for removal of dust and oil mist contained in the high pressurized air obtained by the pressure source 17.

30

In Fig. 3, a first conduit 47 is connected between a first outlet port 15B of the air separator 15 and the laser beam head 7 of the laser beam machine. Further, a first pressure control valve 51A, a first pressure gage 53A and a first change-over (selector) valve 55A are connected midway of the first conduit 47 in sequence. In addition, a muffler (noise eliminator) 57A is connected to the first

change-over valve 55A.

Further, to remote-control the first pressure control valve 51A, a pilot path 59 is branched from a connection pipe 45 (connected between the filter 19 and the air separator 15). A first pilot control valve 61A is connected to the pilot path 59. The first pilot path 63A is connected to the first pressure control valve 51A. Further, a third pressure gage 65A is connected to the 10 pilot path 63A.

On the other hand, a second conduit 49 is connected between a second outlet port 15C of the air separator 15 and the laser beam head 7 of the laser beam machine.

15 Further, a second pressure control valve 51B, a second pressure gage 53B and a second change-over (selector) valve 55B are connected midway of the second conduit 49 in sequence. In addition, a muffler (noise eliminator) 57B is connected to the second change-over valve 55B.

20

Further, to remote-control the second pressure control valve 51B, a second pilot control valve 61B is connected to the first pilot control valve 61A. A second pilot path 63B is connected between the second pilot control valve 61A and the second pressure control valve 51B. Further, a fourth 25 pressure gage 65B is connected to the second pilot path 63B.

30 Further, in Fig. 3, a pressure gage 67 is connected to the first conduit 47 to display the pressure of the assist gas supplied into the laser beam head 7.

In the above-mentioned construction, when the compressed air of the pressure source 17 is supplied to the 35 air separator 15 through the inlet port 15A via the filter 19, since nitrogen and oxygen are separated from the supplied compressed air, nitrogen-rich gas (purity: 94 to

99.5%) is discharged through the first outlet port 15B and the oxygen-rich gas (passed through the polyimide hollow thread membranes) is discharged through the second outlet port 15C of the air separator 15, respectively.

5

Under these conditions, when the first change-over valve 55A is switched to an open state and the second change-over valve 55B is switched to a closed state, the separated nitrogen-rich gas is supplied to the laser beam head 7 as an assist gas. On the other hand, the separated oxygen-rich gas is discharged to the outside through the muffler 57B.

On the other hand, when the first change-over valve 55A is switched to a closed state and the second change-over valve 55B is switched to an open state, the separated oxygen-rich gas is supplied to the laser beam head 7 as an assist gas. On the other hand, the separated nitrogen-rich gas is discharged to the outside through the muffler 57A. 20 In other words, it is possible to selectively supply nitrogen-rich gas or oxygen-rich gas into the laser beam head 7 as an assist gas according to the laser beam processing conditions..

25 The pressure of the nitrogen-rich gas supplied to the laser beam head 7 can be controlled on the basis of the set pressure of the first pressure control valve 51A which can be controlled by the first pilot control valve 61A. In the same way, the pressure of the oxygen-rich gas supplied to 30 the laser beam head 7 can be controlled on the basis of the set pressure of the second pressure control valve 51B which can be controlled by the second pilot control valve 61B.

Here, for instance, when the first pressure control 35 valve 51A is throttled down (the opening rate is reduced), since the volume of the nitrogen-rich gas decreases and the amount of the oxygen-rich gas (passed through the hollow

thread membranes) increases, the purity of the nitrogen-rich gas discharged through the first outlet port 15B increases. In contrast with this, when the first pressure control valve 51A is throttled up (the opening rate is increased), since the gas dischargeability increases on the side of the first outlet port 15B, the amount of the oxygen discharged through the first outlet port 15B increases, so that the purity of the nitrogen-rich gas discharged through the first outlet port 15B decreases.

10

Further, when the second pressure control valve 51B is throttled down on condition that the first pressure control valve 51A is kept at a constant throttle rate (the set pressure is kept constant), since the gas dischargeability decreases on the side of the second outlet port 15C, the amount of the oxygen discharged through the first outlet port 15B increases, so that the purity of the nitrogen-rich gas discharged through the first outlet port 15B decreases.

20

On the other hand, when the second pressure control valve 51B is throttled up on condition that the first pressure control valve 51A is kept at a constant throttle rate (the set pressure is kept constant), since the gas dischargeability increases on the side of the second outlet port 15C, the amount of the oxygen discharged from the first outlet port 15B increases, so that the purity of the nitrogen-rich gas discharged from the first outlet port 15B increases.

30

As described above, it is possible to keep the purity of the nitrogen-rich gas discharged through the first outlet port 15B of the air separator 15 at any desired value by maintaining a difference in pressure between the first and second conduits 47 and 49 at roughly a constant value.

In the laser beam machining, when the purity of the

nitrogen-rich gas obtained through the first outlet port 15B of the air separator 15 becomes less than 94%, dross adheres onto cut-off stainless plate material, for instance. Therefore, in order to cut stainless material, 5 for instance by the laser beam cutting processing without producing any dross, it is necessary to keep the purity of the nitrogen-rich gas supplied into the laser beam head 7 at 94% or higher.

10 In this second embodiment, when the first pilot control valve 61A is operated to change the set value of the first pressure control valve 51A so that the pressure of the nitrogen-rich gas supplied to the laser beam head 7 can be changed according to the machining conditions, a 15 difference in inner pressure between the first conduit 47 and the second conduit 49 changes.

Further, when the second pilot control valve 61B is operated to change the set value of the second pressure 20 control valve 51B, it is possible to set the pressure difference to any desired value, with the result that it is possible to keep the purity of the nitrogen-rich gas supplied from the air separator 15 to the laser beam head 7 at a predetermined value without producing dross during the 25 cut-off processing of the stainless material, for instance.

In other words, even if various pressures of the assist gas are required according to the laser beam processing conditions, it is possible to suppress the 30 fluctuations in purity of the nitrogen-rich gas supplied to the laser beam head 7; that is, to control the purity of the nitrogen-rich gas at roughly a constant level.

In the above-mentioned second embodiment, although the 35 first and second pressure control valves 51A and 51B are adjusted, respectively by operating the first and second pilot control valves 61A and 61B, separately, it is also

possible to control the first and second pressure control valves 51A and 51B by use of two electromagnetic pressure reduction valves, respectively.

5       A third embodiment of the laser beam machine will be described hereinbelow with reference to Fig. 4. In this third embodiment, the first and second pressure control valves 51A and 51B are both operated by use of a link mechanism 69 such as gear or chain link mechanism. That  
10      is, when one of the two pressure control valves 51A and 51B is operated, the other of the pressure control valves 51A and 51B can be operated simultaneously in linkage with the other. In this linkage operation, the first and second pressure control valves 51A and 51B are so linked that a  
15      difference in inner pressure between the first conduit 47 and the second conduit 49 can be always maintained at roughly a constant value.

20      The above-mentioned embodiments have been explained by way of examples. Without being limited only thereto, however, the embodiments can be modified in various ways. For instance, each of the first and second pressure control valves can be replaced with two flow rate control valves having an adjustable throttle, an adjust value, etc.,  
25      respectively. Further, the two change-over valves 55A and 55B can be assembled into a single change-over valve.

30      Further, when the laser beam machining conditions are roughly constant and therefore only the nitrogen-rich gas is used as an assist gas, it is possible to control the pressure of the nitrogen-rich gas supplied to the laser beam head 7 by use of only the first pressure control valve 51A arranged in the first conduit 47. In this case, the second outlet port 15C of the air separator 15 is left  
35      released to the atmospheric pressure. In this case, however, since it is preferable that the purity of the nitrogen-rich gas supplied to the laser beam head 7 is kept

at 94% or higher, the first control valve 51A is controlled in such a way that a pressure difference between the first output port 15B and the second outlet port 15C can be maintained within a predetermined desired range.

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#### Industrial Applicability

As described above, in the laser beam machine according to the present invention, since the nitrogen-rich gas containing an extremely small amount of oxygen and moisture is supplied into the optical path system at pressure higher than the atmospheric pressure, it is possible to effectively prevent fire accident of the optical path system and to protect the optical parts from deterioration due to oxidization and moisture, as compared with the conventional dry air.

Further, in the laser beam machine according to the present invention, since the nitrogen-rich gas can be also supplied to the laser beam head as an assist gas, it is possible to effectively use the nitrogen-rich gas separated by the air separator. Further, oxygen gas separated by the air separator can be also used as an assist gas.

Further, in the laser beam machine according to the present invention, since the nitrogen-rich gas can be supplied to the laser beam head as an assist gas by keeping the purity of the nitrogen-rich gas or the oxygen-rich gas at a desired constant level or in a predetermined range (e.g., 94 to 99.5%) at all times, it is possible to prevent the occurrence of dross during the laser beam processing.

Further, in the laser beam machine according to the present invention, since the first filter for removing dust from air supplied to the air separator and the second filter for removing oil mist from the separated nitrogen supplied to the optical path cover, it is possible to

improve the lifetime of the optical parts of the optical path system.

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## CLAIMS

1. A method of supplying nitrogen gas into an optical path system of a laser beam machine, which comprises the following steps of:
  - 5 supplying compressed air into an air separator (15) for separating oxygen and nitrogen from the supplied compressed air; and
  - 10 introducing nitrogen-rich gas separated by the air separator into an optical path cover (11) of the optical path system (13) of the laser beam machine, to maintain an inner pressure of the optical path cover at a pressure higher than outside air pressure.
- 15 2. The method of supplying nitrogen gas into an optical path system of claim 1, which further comprises the step of passing the nitrogen-rich gas separated by the air separator through a filter (33) for removing oil mist, before the nitrogen-rich gas is introduced into the optical path cover (11) of the optical path system (13) of the laser beam machine.
- 20 3. An apparatus for supplying nitrogen gas into an optical path system of a laser beam machine, which comprises:
  - 25 an air separator (15) for separating oxygen and nitrogen from compressed air; and
  - 30 conduit means (23) for introducing nitrogen-rich gas separated by said air separator into an optical path cover (11) of the optical path system (13) of the laser beam machine.
- 35 4. The apparatus for supplying nitrogen gas into an optical path system of claim 3, which further comprises:
  - 35 a first filter (19) for removing dust from the compressed air, before the compressed air is supplied to said air separator; and

a second filter (33) for removing oil mist contained in the nitrogen-rich gas, before the nitrogen-rich gas is introduced into the optical path cover of the optical path system of the laser beam machine.

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5. A laser beam machine, comprising:
  - an air separator (15) for separating oxygen and nitrogen from compressed air;
  - first conduit means (23) for introducing nitrogen-rich gas separated by said air separator into an optical path cover (11) of the laser beam machine as a protective gas; and
  - second conduit means (39, 41, 47) for introducing the nitrogen-rich gas separated by said air separator into a laser beam head (7) of the laser beam machine as an assist gas.

6. The laser beam machine of claim 5, which further comprises:

- 20 a first filter (19) for removing dust from the compressed air, before the compressed air is supplied to said air separator; and
- a second filter (33) disposed in said first conduit means (23), for removing oil mist contained in the nitrogen-rich gas, before the nitrogen-rich gas is introduced into the optical path cover of the laser beam machine.

7. The laser beam machine of claim 5, wherein said second conduit means is a conduit (39) connected between the optical path cover (11) and the laser beam head (7), for supplying the nitrogen-rich gas into the laser beam head as the assist gas.

- 35 8. The laser beam machine of claim 5, wherein said second conduit means is a branch conduit (41) connected between said air separator and the laser beam head (7), for

supplying the nitrogen-rich gas into the laser beam head as the assist gas.

9. The laser beam machine of claim 5, wherein said second 5 conduit means comprises:

a first conduit (47) connected between a first outlet port (15B) of said air separator (15), for discharging the nitrogen-rich gas; and

10 a second conduit (49) connected between a second outlet port (15C) of said air separator (15), for discharging the oxygen-rich gas.

10. The laser beam machine of claim 9, which further comprises:

15 a first change-over valve (55A) disposed midway of said first conduit (47), for supplying the nitrogen-rich gas into the laser beam head when opened; and

20 a second change-over valve (55B) disposed midway of said second conduit (49), for supplying the oxygen-rich gas into the laser beam head when opened.

11. The laser beam machine of claim 10, which further comprises:

25 a first pressure control valve (51A) disposed midway of said first conduit (47), for controlling pressure in said first conduit; and

a second pressure control valve (51B) disposed midway of said second conduit (49), for controlling pressure in said second conduit.

30 35 12. The laser beam machine of claim 11, wherein purity of the nitrogen-rich gas increases when the pressure in said first conduit is increased by said first pressure control valve (51A), but decreases when the pressure therein is decreased thereby.

13. The laser beam machine of claim 11, wherein purity of

the nitrogen-rich gas increases when the pressure in said first conduit is kept constant by said first pressure control valve (51A) and when the pressure in said second conduit is decreased by said second pressure control valve 5 (51B), but decreases when the pressure in said first conduit is kept constant by said first pressure control valve (51A) and when the pressure in said second conduit is increased by said second pressure control valve (51B).

10 14. The laser beam machine of claim 11, purity of the nitrogen-rich gas can be kept roughly constant when a difference in pressure between said first and second conduits (47, 49) is kept roughly constant.

15 15. The laser beam machine of claim 11, which further comprises:  
a first control valve (65A) for remote-controlling said first pressure control valve (51A); and  
a second control valve (65B) for remote-controlling 20 said second pressure control valve (51B).

16. The laser beam machine of claim 11, which further comprises an link mechanism (69) for controlling said first and second pressure control valves (51A, 51B)  
25 simultaneously in linkage so that a difference in pressure between said first and second conduits (47, 49) can be kept roughly constant.

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FIG. 1

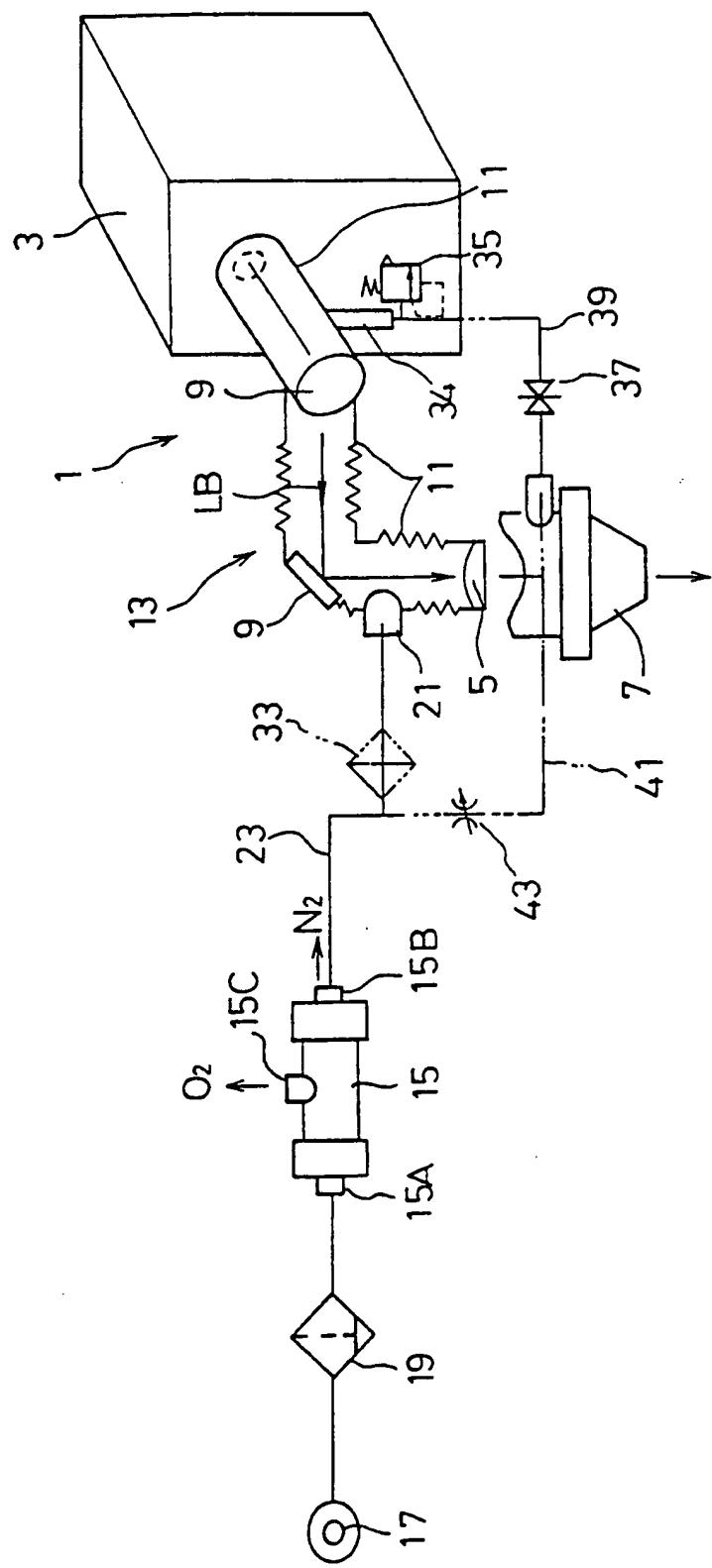


FIG.2A

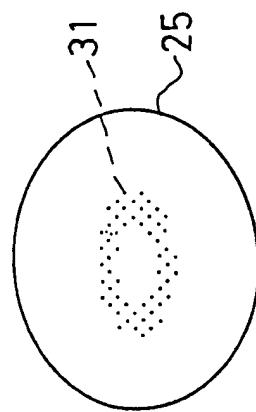
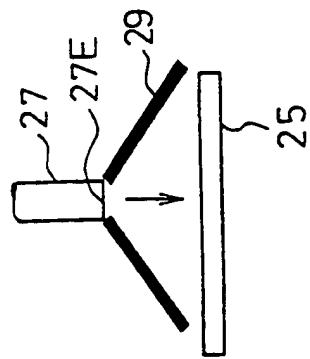


FIG.2B

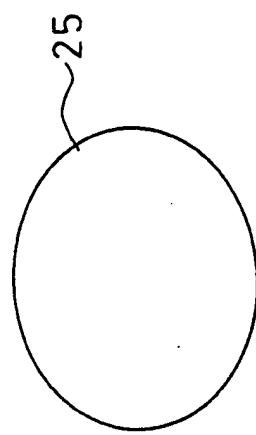
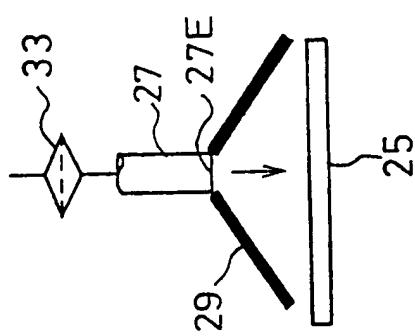


FIG. 3

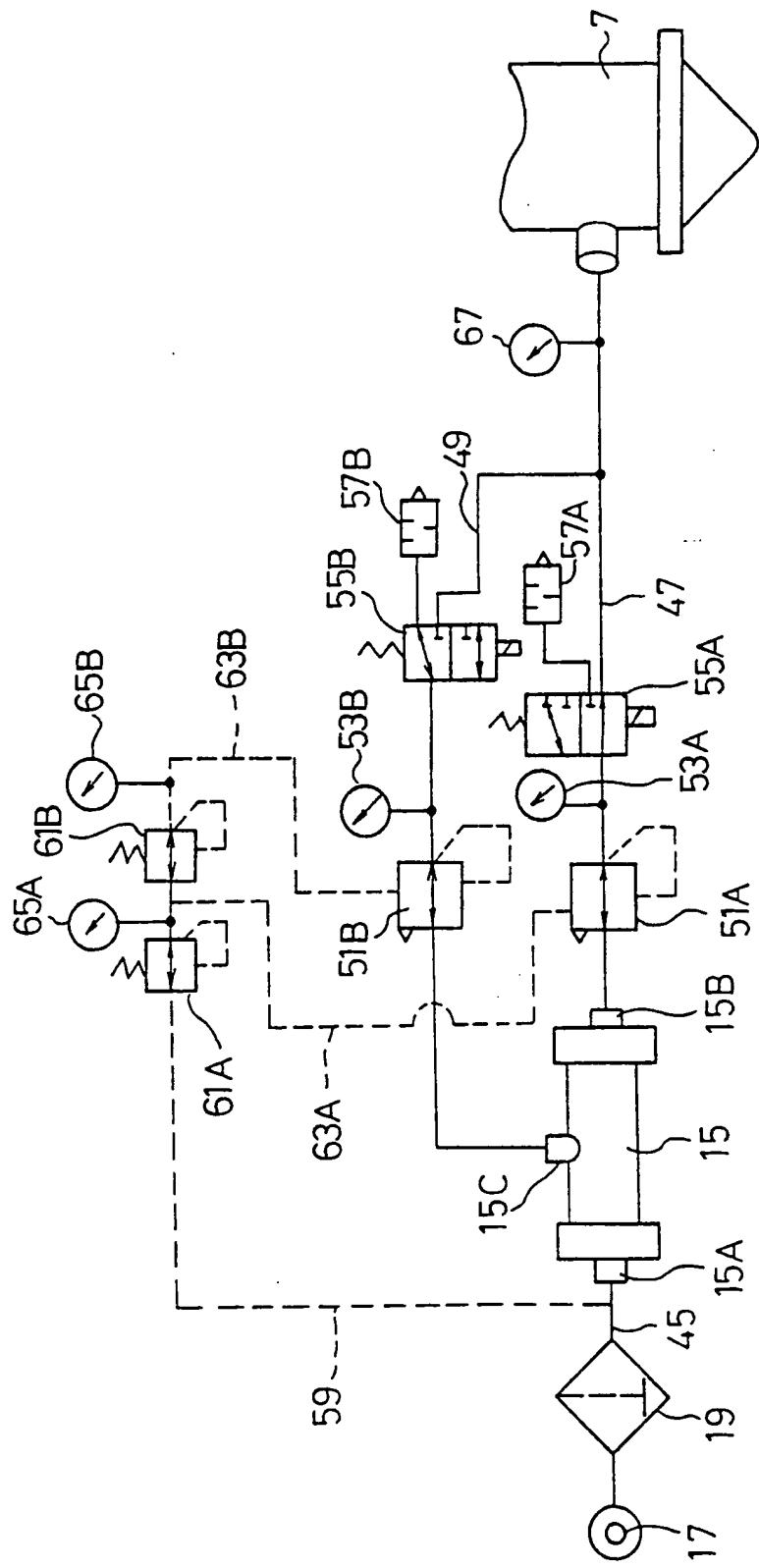
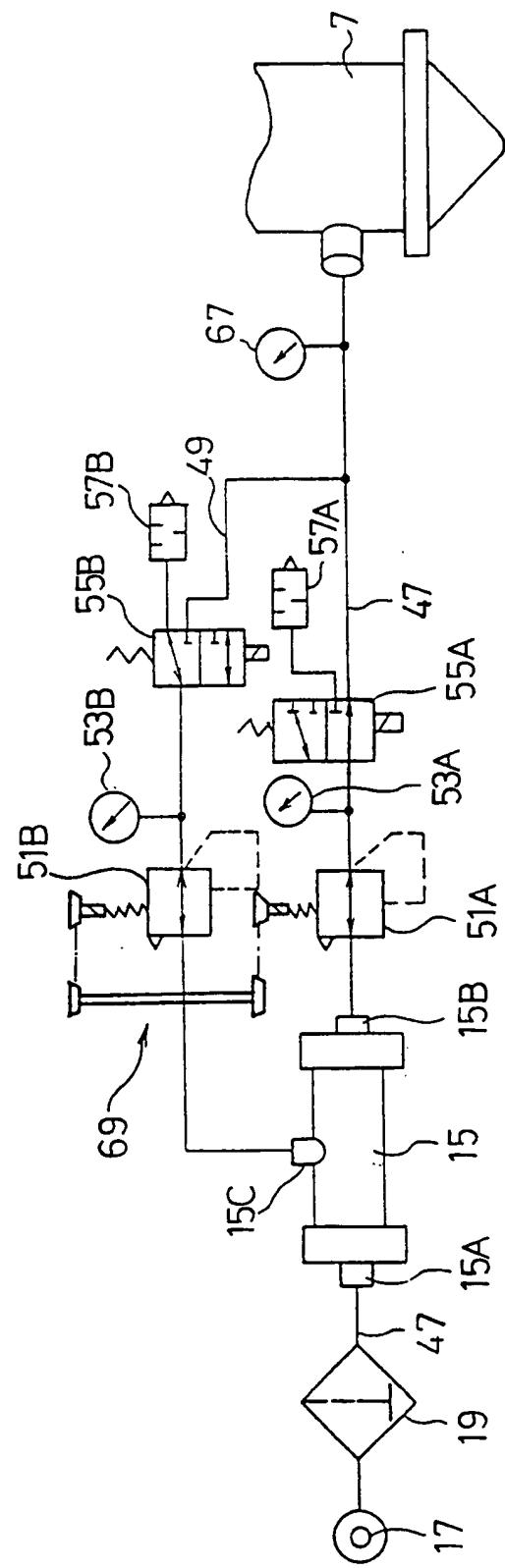


FIG. 4



## INTERNATIONAL SEARCH REPORT

International Application No

PCT/JP 95/01090

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 B23K26/14

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 B23K H01S C01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 17 no. 410 (M-1455) ,26 September 1993 & JP,A,05 084590 (AMADA CO. LTD) 6 April 1993, cited in the application see abstract ---	1-6,10, 11,15
A	DE,A,39 06 571 (FESTO KG) 6 September 1990 see the whole document ---	1
A	US,A,4 977 566 (HERBST ET AL.) 11 December 1990 see claims 1-15 ---	1-6
A	EP,A,0 148 405 (MESSER GRIESHEIM GMBH) 17 July 1985 -----	1-16

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1 Date of the actual completion of the international search

28 September 1995

Date of mailing of the international search report

06-10-1995

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A	DE,A,39 06 571 (FESTO KG) 6 September 1990 see the whole document ---	1
A	US,A,4 977 566 (HERBST ET AL.) 11 December 1990 see claims 1-15 ---	1-6
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